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Concrete: Its History in Florida to World War II

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CONCRETE
ITS HISTORY IN FLORIDA TO WORLD WAR II

BY

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CHAPTER I

INTRODUCTION

One can deduce a great deal about a society from studying the types of structures that are built by that society. The Egyptians built pyramids to shelter the body's undying soul, and the pyramids still stand. The Roman engineers selected the most durable materials available for the construction of their water systems, roads and buildings, and Rome ruled much of the civilized world for a thousand years. The Chinese built a great wall, not to keep invaders out for days or months or years, but for centuries. The great cathedrals of Europe were constructed not for one generation to worship in, but for use by many generations to practice their faith and perpetuate their beliefs.

The knowledge, the wealth, the attitude of a society are recorded in its structures. A society with a sense of responsibility and a desire to provide for the well-being of its decendents, built accordingly.

Throughout the history of mankind, the construction materials chosen by the builders reflected the state-of-the-art of construction, the wealth of the owner and the expected length of time that the structure was to be used. But the builder's choice of materials has been limited by the availability of the elements around him and his ability to understand the actions of those elements subjected to the forces of nature. It has been, and will continue to be, a formidable task.

The most durable materials used by man have been those that are in balance with nature's forces, those that have reached a condition of physical stability with the surroundings.

Early builders knew that if they were to build a structure that would endure for centuries, they had to choose a construction material that had endured for centuries. And so the ancient builders, the Egyptians, Romans, Chinese and later the cathedral builders, chose stone.

The Romans, possibly recognizing the origin of stone from beneath the earth's crust, used volcanic materials to make their own stone. With this man-made stone they built structures otherwise impossible for them to build. And those structures, destroyed more by the forces of man than by forces of nature, have endured. This man-made stone developed by the Romans was concrete.

Long after the natural destructive cycle of nature breaks down the bonding forces of wood and metal, stone and concrete will remain. It is inconceivable that a member of a future generation can stand upon the walls of an ancient stone fort or walk the perimeter of the ruins of an early concrete building without asking, why is it there? When was it built? Who built it?

The first concrete structures built in America stand today on Florida soil. And if they can withstand the destructive forces of man, they will surely withstand the destructive forces of nature. This paper has attempted to identify some of the earliest of Florida's stone and concrete structures and provide a history of the developmental process that provided the material and design knowledge for their existence.

The man-made stone, concrete, is a mixture of cement, aggregate (such as sand, rock or shell) and water. The water provides an important element that combines the cement with the aggregatè to form, when using the proper proportions, a material in harmony with nature.

A description of the various types of cements that have been used by the builder is presented with the history of their use and development. Florida's first concrete structures are discussed, beginning with the tabby homes of St. Augustine and Florida's nineteenth century plantations, leading into our modern era of portland cement concrete and the envisionaries who used it. The discussion stops with the United States involvement in World War II. At that time the use of concrete in Florida expanded at such a rapid pace that the documentation of its use far exceeds the scope of this paper.

A discussion of masonry structures would be lacking without mention of Florida's early coquina masonry structures, among the first masonry structures in the United States.

Man-made or manufactured concrete masonry was so compatible with Florida's climate that its use was very widespread after its introduction. An attempt was made to list only a few examples that represented the many structures that were built with this material.

A section is included which presents the development of early material standards, specifications, and building codes. While general in nature, it presents an overview of the evolution of an important aspect of "modern" concrete construction.

A brief history of the organizations so instrumental in the advancement of the use of concrete prior to World War II is included.

It was not within the scope of this paper to document or discuss all of the early masonry or concrete structures in Florida, but a diligent attempt was made to assimilate information on representative types of such structures. The author regrets the omission of the names of early designers and builders and their work which was not located during the research for this paper.

While the owners and political and economic events that generate the birth of a structure are generally well documented, the names of the artisans who are truly responsible for its existence are often not recorded. History is much richer if the designers and builders are also remembered. It seems only fitting that an attempt be made to assemble a collection of facts about Florida's natural or man-made stone structures so that future generations have knowledge of the who, what and why of the skeleton remains that they will encounter.

CHAPTER II

CEMENT

The ingredient in concrete that provides the binding strength is the cement. An hydraulic cement reacts with water to form a hardened material that is water-resistant. There are four different types of hydraulic cement: pozzolanic lime, hydraulic lime, natural cement and portland cement (Hool and Johnson 1929, p.992).

Pozzolanic Lime

Pozzolanic lime is formed by the reaction between reactive silica, slaked lime and water at room temperature. Reactive silica can be found in nature in the form of diatomaceous earth of volcanic ash or may be manufactured, such as industrial fly ash (Hansen 1966, p.201).

Roman Cement

The Romans developed considerable ability in making and using pozzolanic lime which they made from tuff, a volcanic rock or sand, found near Pouzzol (Draffin 1976, p.6). Pozzolanic lime was used to make concrete to cover the enormous dome of the Pantheon which spanned 142 feet 6 inches. The walls of the Pantheon were concrete covered with brick facing. The circular podium around the temple of Vesta, about 10 feet high, was of concrete. The great platform in Nero's palace and the pyramid of Cestius were also of concrete (Smith, 1890).

The use of pozzolanic lime diminished with the fall of the

Roman Empire, during a period in which little organized effort was made to advance science (Beakly and Lech 1979, p.13).

Civilization was entering the Dark Ages (A.D. 500-1000). While basic skills survived, there was a breakdown in the education process. Scientific knowledge was dispersed among small groups. Scholarship and science reached a low ebb (Brinton 1960, p.175). However, the desire and need to build continued. It was during this period that the magnificent cathedrals of Europe were built. While it is assumed that some lime mortar was used during this period, there is no record of the use of concrete.

The Middle Ages experienced a reawakening of scientific thought. There would be established a trend to learn by experimentation. The scientific process would be revived. The era of exploration and discovery of new worlds would also bring about the re-discovery of concrete.

Hydraulic Lime

In 1671, Manuel de Cendoya arrived in St. Augustine with the authorization to build a stone fort. He brought masons and lime-burners from Cuba who built kilns just north of the site for the Castillo de San Marcos. In the kilns, oyster-shells were heated until white hot, transforming them into a fine quality lime (Arana 1977, pp. 17-18).

Hydraulic lime, made from oyster shell, was used for mortar in their coquina masonry construction and mixed with coquina shell and water to produce a rough, but durable concrete which the Spanish called tapia or "tabby."

Development of Hydraulic Limes

The first steps toward the development of modern cement was in the development of hydraulic limes. John Smeaton (1724-1792) is credited with developing the foundation upon which our knowledge of hydraulic mortar is based. While preparing to rebuild the Eddystone Lighthouse in England in 1756, Smeaton performed extensive experimentation on limes revealing the importance of argillaceous soil to increase the strength of lime mortar and permitted it to harden underwater (Draffin 1976, p.6).

J. L. Vicat (1786-1861), a French engineer, pinpointed that for a lime or cement to possess hydraulic properties, it was necessary that lime, silica, alumina, manganese, magnesia and iron must be present when manufactured. There were many that followed Vicat who contributed to the development of limes and cements one of whom was James Parker (Draffin 1976, p.7).

Natural Cement

James Parker was granted a patent for manufacturing natural cement in England in 1796 (Draffin 1976, p.7). His natural cement, made from argillaceous limestone, was used in the construction of the Thames River Tunnel (Portland Cement Association 1975, p.15).

Simultaneous to Parker's work, a French military engineer named Lesage was producing a similar cement in Boulogne-Sur-Mer, France (Draffin 1976, p.7).

In 1822, James Frost received a patent for the manufacture of a natural cement called "British Cement," which resulted from the processing of specific proportions of limestone or marl containing silicious earth. Frost built the first cement factory in 1825 at Swanscombe, England (Portland Cement Association 1975, p.15).

In the United States, the need for cement increased rapidly with the construction of the canal projects beginning in 1817. Canvass White, an engineer on the Erie Canal project, manufactured the first natural cement in the United States in 1818 near Madison County, New York (Draffin 1975, p.8).

Portland Cement

In December, 1824, Joseph Aspdin (1779-1855), a bricklayer in England, was granted a patent for his process of manufacturing a new and improved cement. He called it portland cement because the mortar produced with it resembled the color of the natural stone found in the Isle of Portland. His son, William Aspdin (1816-1864), directed the manufacture of this cement in a plant located at Rotherhithe on the banks of the Thames River. A cement works at Wakefield supplied cement for use in the Thames River Tunnel in 1828, which is though to be the first use of portland cement for engineering purposes (Draffin 1975, p.10).

The popularity of portland cement grew because of its successful use in the construction of the sewerage system in London from 1857-1859. The product needed considerable refinement, and Isaac Charles Johnson (1811-1911) did much to refine the process resulting in a cement of much more consistent quality (Draffin 1975, p.10).

Portland Cement in the United States

In 1871, David O. Saylor became the first American to be granted a patent for the manufacture of portland cement. In 1866, Saylor, Adam Woolever and Esaias Rehrig organized the Coplay Cement Company (Murphy 1976). In 1871, the first cement was shipped from their cement plant, the first successful plant in the United States, in Coplay, Pennsylvania (Draffin 1975, p.11).

Most of the early cement plants used vertical dome or bottle kilns. An important improvement in the manufacturing process was due to improvements to the kiln (Draffin 1975, p.12).

In 1866, Jose F. Navarro (1823-1909) introduced the first inclined rotary kiln. Though this first rotary kiln proved unsuccessful, he built a successful one in 1889 under the patents of Frederick Ransome of England. This first generation of successful rotary kilns was about twenty-five feet long and five feet in diameter. They were gradually enlarged, and in 1909 Thomas Edison secured patents on rotary kilns ranging in size from 150 feet long and 7 to 8 feet in diameter to 260 feet long. These kilns were capable of producing 1000 barrels of cement per day (Draffin 1975, p.12), an impressive improvement over the vertical kilns which produced 200 barrels every ten days ("Pioneer Cement Plant Now Industry's First Museum," 1976).

In 1898 there were ninety-one different formulas for making portland cement (The World Book Encyclopedia 1952, p.1304). The need for more consistent quality lead to the adoption of the first standard specifications for cement in 1904 (Draffin 1975, p.17).

The first large demand for cement in the United States was for the canal projects. The obvious means of transporting cement was by barge which necessitated watertight packaging. Five bushel barrels lined with oiled paper containing 376 pounds of cement were used. As the demand for cement increased, it became necessary to package cement in cheaper, more easily handled containers. The quantity of cement in the barrel was divided into four equal units of 94 pounds each and packaged in sacks ("History and Heritage" 1982, pp.100-101).

The 94 pound sack proved to be a convenient quantity since it occupied approximately one cubic foot of volume, and early proportioning practice was by volume.

It was the cement industry's concern over the expense of packaging their product that prompted the cement manufacturers to meet in 1902 to exchange ideas on the subject. This meeting resulted in the formation of the Portland Cement Association (Lesley, Cober and Bartlett 1972, pp.196-202).

Portland Cement Manufacturing in Florida

In a report written to the southern division of the American Mining Congress (around 1925) Dr. Henry M. Payne, a consulting engineer, stated,

> Down in Florida they use 1,200,000 barrels of cement a year. They developed an exceptionally fine deposit of high-grade limestone in central-western Florida, along the line of a railroad that had just recently been opened. I suggested to the industrial agent of that railroad that there was a very logical opportunity for him to get in touch with cement people and to develop the cement industry in Florida, and he did so. A 700,000 barrel plant is being put there today. (Perry 1926, pp.130-131)

The first cement plant in Florida was built by the Florida Portland Cement Division of General Portland Cement Company and began operations in 1927. The plant was located on a fifteen-acre plot at Hooker's Point in Tampa, chosen because of the available water and rail transportation (Lamme 1942, p.10).

To provide adequate structural support for buildings, 21,000 piles were driven through soil dredged from McKay Bay. Three cylindrical rotary kilns heated by pressure oil burners and fed automatically processed limestone from Brookesville and clay from Citrus County to produce approximately 1,500,000 barrels of portland cement annually (Lamme 1942, p.10).

CHAPTER III

TABBY

Tabby was a mixture of burned hydraulic lime, pebbles or oyster shell, sand and water which hardened into a durable primative concrete suitable for floors, walls and roofs. Tabby was used extensively by the Spanish during their first period of rule in St. Augustine and later was a prominent feature on Florida plantations.

Tabby Houses (St. Augustine)

Manucy (1978) tabulated the number and type of houses in St. Augustine from maps prepared in 1764, a year after the end of the first Spanish rule, and again in 1788. Of 336 houses in 1764, 132 (39 percent) were constructed of tabby. By 1788 only 13 of 263 were of tabby, a reduction of 119 houses. Many were destroyed by English soldiers when they were pushed down in order to salvage firewood.

The construction technique used by the Spanish to construct their tabby walls was detailed by a Quaker botanist, John Bartram:

> Most of the common Spanish houses were built of oyster shells and mortar... They raised them by setting two boards on edge... Then poured in lime-shell mortar mixed with sand, in which they pounded oyster shells as close as possible. And when that part was set, they raised the planks, and so on till they had raised the wall as high as wanted. (See Figure 1) (Manucy 1978, pp. 32-33)

The lime used in the mortar hardened slowly and construction might well have taken months. One means of reinforcing the green

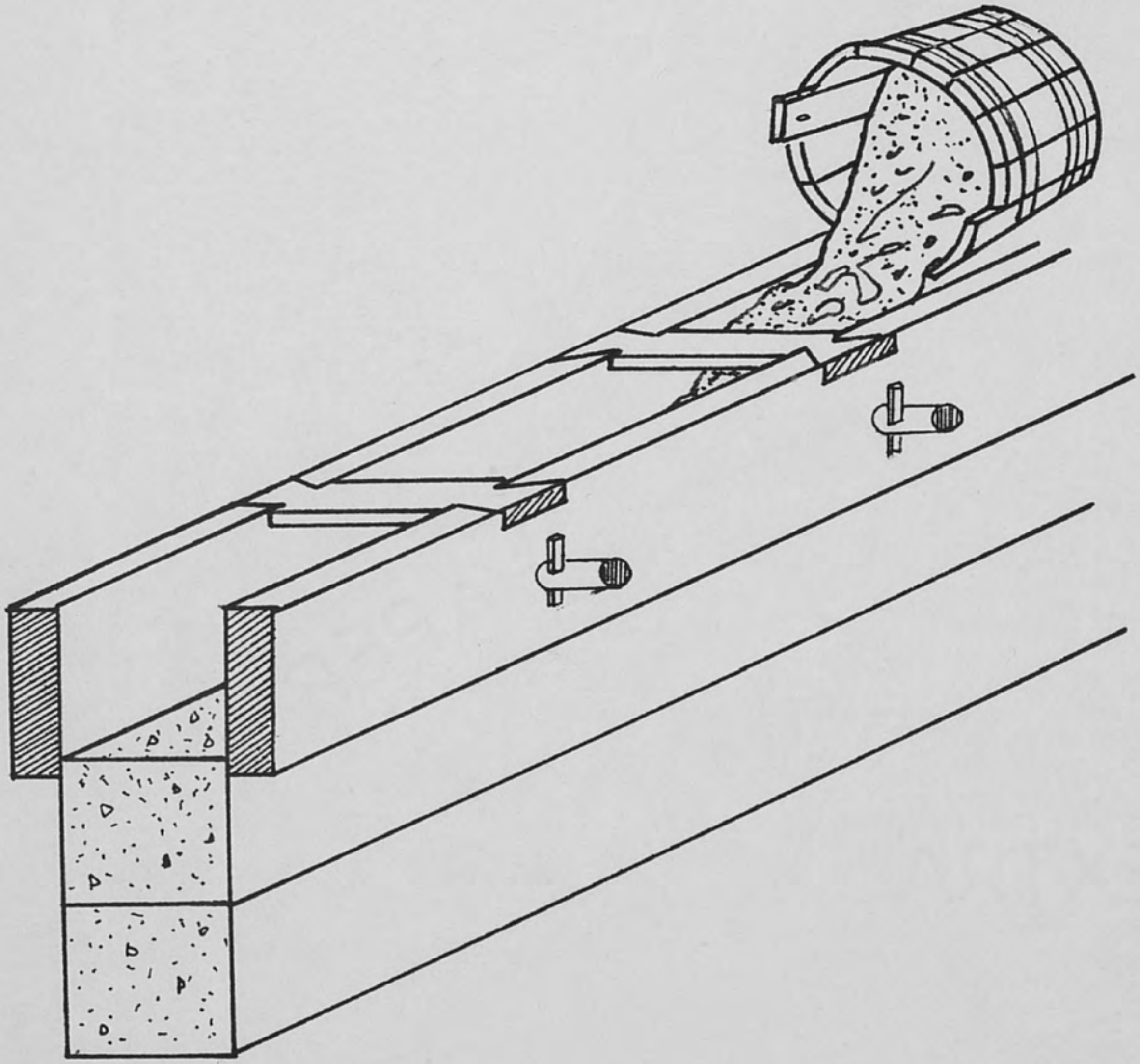


Figure 1. Pouring a tabby wall

mortar and expediting construction of walls was the insertion of vertical and horizontal posts at 5-foot intervals (Manucy 1978, p.69).

Tabby on Florida's Plantations

The economy of Florida prior to the Civil War was predominately agricultural based. The population of the state doubled from 70,000 in 1845 to 140,000 in 1860, due primarily to agricultural expansion. Prominent in this expansion was the growth of Florida's plantation system supported by slave labor. Slaves comprised over forty percent of the population in 1860 (Tebeau 1971, pp.181-183).

Florida's plantations were developed in the late 1700's and early 1800's. Not all of these early settlers were welcomed by Florida's Indians. A plantation owner constructing buildings miles from the nearest neighbor was wise to select a building material that would withstand the impact of a hostile musket ball and resist destruction by a torch. Two materials that provided such characteristics were tabby and coquina stone.

Constructed around 1842, the Gamble Plantation in Manatee County used thick tabby walls. Arriving in Manatee County at the same time as Gamble, Dr. Joseph Braden erected a tabby house called "Braden Castle" near the present location of Bradenton (Tebeau 1971, p.183).

The oldest standing plantation house in Florida is located on Ft. George Island, just north of Jacksonville. John Houston MacIntosh purchased the plantation in 1804, moving his family from a tabby home three miles from the plantation. In 1817, the plantation was sold to Zepheniah Kingsley. The cotton and sugar cane plantation was developed through the efforts of negro slaves, whose tabby cabin ruins stand along two semi-circular arc paths, so oriented to allow the constant watch of the slaves by the overseer (Edwards 1979).

CHAPTER IV

PORTLAND CEMENT CONCRETE

Modern concrete is a mixture of portland cement, aggregate and water. The physical properties of the concrete in its plastic (wet) and hardened state is dependent upon the characteristics and proportions of the ingredients used.

Portland cement and water mixed together form a paste, the binding element in the mixture, which occupies 20 to 40 percent of the total volume of the concrete. The remaining 60 to 80 percent is filled by aggregate (sand and small rock).

A properly proportioned mixture is the most economical blend of materials that will provide strength, durability and other requirements specified by the engineer.

Proportioning Mixes

The first method of proportioning concrete was by specifying the volume of materials to be used. A "1:2:4 mix" indicated that one part (by volume) of cement was to be blended with two parts sand and four parts rock or stone with enough water added to cause the paste to form (Draffin 1976, p.23).

The first comprehensive study of proportioning mixtures was performed by Rene Feret in France, who released his findings in 1892 and in 1897. Feret concluded that the strength of the cement paste was a function of the ratio of the volume of cement to the volume of water and air voids (Draffin 1976, p.23).

In 1907, William B. Fuller and Sanford E. Thompson published their paper (Blanks et al. 1940, p.438) which stated basically the same conclusion as Feret, that the less the amount of voids present, the stronger the mixture (Draffin 1976, p.24).

In 1918, Edwards presented a "surface-area" method of proportioning stating that the strength of a mortar was a function of the amount of cement and surface area of the aggregate. Edwards also recognized that excessive water was detrimental to the strength of the concrete (Draffin 1976, p.24). R. B. Young, in 1919, conducted further research on the surface area theory concluding that a concrete mixed with aggregate having the least surface area will require the least excess water and will be the strongest (Blanks et al. 1940, p.439).

In 1919, Duff A. Abrams disclaimed the surface area theory, proving that a wide variation in the surface area of aggregate could be experienced with little change in concrete strengths. He proposed using the aggregates' "fineness modulus" and showed that the most important factor in controlling the strength of concrete was the relationship of the amount of water to the amount of cement (water-cement ratio) (Blanks et al. 1940, p.440).

In 1923, A.N. Talbot and F.E. Richart concluded that it was not so much the water-cement ratio that controlled concrete strength, but the void-cement ratio; the voids in the concrete being the sum of the volume of space occupied by water and air after the concrete is in place (Draffin 1976, p.25).

In 1940, Blanks, Vidal, Price and Russell presented a paper prepared primarily for an American Concrete Institute's committee to consider in formulating a "Recommended Practice for the Design of Concrete Mixes." Some of the major conclusions were as follows:

> 3. No theoretical procedure for designing concrete mixes has yet been evolved which can be generally applied to all materials ...
>
> 9. Consistency as measured by the slump test ... is the most practical method yet devised for controlling workability ...
>
> 11. The water-cement ratio is the most significant factor affecting ... the strength ... of the hardened concrete ...
>
> 29. The basic measure for proportioning the materials in a concrete mix is the absolute volume of the individual materials. (Blanks et al. 1940, pp.469-471)

These principles were adopted and are still in use today.

Mixing Concrete

In 1885, Ernest L. Ransome invented a cylindrical-drum, paddle-type mixer which would serve as the prototype that would replace the practice of unskilled laborers mixing concrete by layering the materials, adding water and turning with a shovel ("Landmarks in the History of Concrete" 1981, p.1032).

By the 1920's the drum mixer was the most commonly used device for mixing conrete. Gravity mixers, consisting of a series of large funnels suspended one above another permitting the material to flow from one into the other were seldom seen anymore. Trough mixers of the paddle or shovelling type were useful for mortar and plaster mixing (Hool and Johnson 1929, p. 880).

Transit-mix or Ready-mixed Concrete

The first moving concrete mixer on record was used around 1909 in Sheridan, Wyoming. It consisted of a 2-1/2 foot cube supported on a single axle drawn by two horses ("Landmarks in the History of Concrete" 1981, p.1036).

Around 1913, the first motor truck to be used to deliver concrete was used in Baltimore. The bodies varied in shape and some were equipped with an agitator to prevent the concrete from segrating. In 1916, Stephan Stephanian of Columbus, Ohio, applied for a patent on a self-discharging, horizontal drum-type motorized transit mixer (see Figure 2). The patent office denied the patent because they believed that there was no need for a combination truck and mixer ("History and Heritage" 1982, p.100).

By the 1920's transit mixers were not uncommon. Two types were popular. One type consisted of a cylinder mounted horizontally on a truck discharging the concrete by lifting the entire drum behind the truck's cab. Another type consisted of a rectangular-bed truck which re-mixed the concrete as it was discharged out the rear by lifting the front of the truck bed (Hool and Johnson 1929, pp.884-885).

By 1930, the use of transit-mixers was so popular that the American Concrete Institute proposed the first specifications for ready-mixed concrete (Clair 1930, p.467).

In 1937, truck manufacturers switched to inclined cylindrical mixers which had the rear end raised. Developed by T.L. Smith, this provided easier and more rapid discharge of concrete. Mixers increased in size from 1-1/2 cubic-yar capacities to 3, 4, and 5 cubic-yard

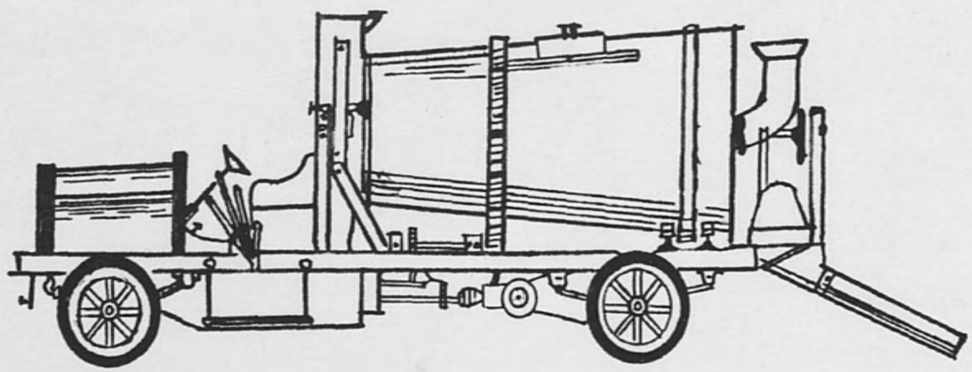


Figure 2. Stephan Stephanian's self-discharging transit mixer. (Redrawn and adapted from "History and Heritage" 1982, p.98).

Ready-mixed concrete in Florida

In 1934, Rinker Materials Corporation became the first company in Florida to offer transit-mix or ready-mixed concrete. The first ready-mix truck was a GMC equipped with a 1-1/2 cubic-yard Rex Mixer purchased in Milwaukee, Wisconsin (Rinker Materials Corporation 1982).

Rinker Materials Corporation had been started in 1926 by Marshall E. Rinker. Originally named Rinker Rock and Sand Company, the company's first office, a pressed fiberboard shed purchased for $15 from a tourist camp, was located in Delray Beach. In 1927, the "office" was moved to Roseland Drive in West Palm Beach. In 1937, the present site at Railroad Avenue was purchased. A block plant was added in 1938 which had a capacity of 2,000 blocks per day (Rinker Materials Corporation 1982).

CHAPTER V

BUILDINGS AND BRIDGES

As the properties of concrete became more familiar to the designer and builder, the use of concrete in buildings and bridges became more popular. Concrete has the ability to resist compressive stresses, but has very little ability to resist tensile stresses. This inherent weakness was overcome by combining a material with concrete that would resist the tensile stresses and thus "reinforce" the concrete. Iron was used initially, but was replaced with steel when it was developed.

Reinforced Concrete

The first clearly documented attempt to use tensile reinforcement in concrete or masonry construction was in 1832. Sir Marc Isambard Brunel used strips of hoop iron and wood to reinforce an experimental arch of brick and cement on the Thames River (Draffin 1976, p.29).

In 1850, Lambot built a small rowboat of reinforced concrete in France (Draffin 1976, p.29). In 1855, Francois Coignet received an English patent for a two-way grid system of iron bars embedded in a concrete floor and secured to the walls, though his description of the system implied that it was more an alternative buttress system for wall support than self-supporting floor system (Collins 1959, p.29). Joseph Monier reinforced garden pots and tubs of concrete with an iron wire mesh receiving a patent in 1867 (Draffin 1976, p.29).

Reinforced Concrete in the United States

Early advances in reinforced concrete had been achieved in Europe, but during the latter part of the nineteenth century the rapid growth in the United States created a demand for improved building materials. Fire had created a phobia in the country that inspired early pioneers in concrete construction to develop adequate fire-proof buildings.

The desire to develop a fire-safe house drove W.E. Ward to construct the first documented reinforced concrete building in the United States. After extensive experimentation, much of it performed during construction, Ward built a reinforced concrete house in Port Chester, New York, in 1875. Ward reinforced concrete beams with iron I-beams placing the iron near the bottom of the beam "... to utilize its tensile quality for resisting the strain below the neutral axis..." (Ward 1976, pp.105-108).

Thaddeus Hyatt appeared to be the first to use an analytical approach to reinforced concrete design from his work performed in the early 1870's. Hyatt recognized the uneconomical aspects of using structural shapes and proposed using top and bottom reinforcing iron in floor systems. He introduced the concept of balanced design with a cross-section of concrete resisting compression stresses above the neutral axis balancing tensile stresses resisted by iron below the neutral axis. Hyatt also established that expansion and contraction characteristics of iron and concrete were practically the same. In addition, he described the phenomenon of horizontal shear in a bending beam (Hyatt 1976, pp.55-76).

Arthur N. Talbot performed extensive experimentation of reinforced beams, releasing his results in 1904. This and subsequent investigations advanced the structural engineers understanding of the failure mechanism of reinforced concrete members (Talbot 1976, pp.123-190).

Arthur Lord's testing in 1910 of an actual floor slab of an eleven story reinforced concrete building under construction in Minneapolis, Minnesota, lead to the conclusion that bending moments in a interior panel of a flat slab are greatest near the supports. Subsequent investigations led Lord to propose a method of slab analysis and design that involved the division of a slab into "beam strips" (Lord 1976, pp.193-241).

Dean H.M. Westergaard performed extensive mathematical analysis in 1921 which he later used as a basis for design formulas for slabs and beams (Draffin 1976, p.34).

Ernest L. Ransome spent most of his life working with concrete. In 1889, he had introduced the first ribbed floor system; and in his book Reinforced Concrete Building, published in 1912, he proposed using a wet, fluid concrete mixture instead of the commonly used dry mixes. While this "wetter" mixture provided for easier placement, others, unfortunately would take it to an extreme; and examples of weak concrete form mixtures that were too wet were not uncommon (Newlon 1976, p.42).

Concrete Buildings in Florida

The first poured portland cement concrete buildings in Florida were built in the 1880's in St. Augustine. Except for reinforcement adjacent to and over openings, the walls of these early structures were of plain concrete. The lack of design experience resulted in thick, expensive walls (see Figure 3) that would discourage use except by the wealthy until design theory allowed for less expensive reinforced column and beam skeleton construction. This affordable construction procedure was popular for hotels and other tall structures constructed during the boom of the 1920's.

Villa Zorayda (St. Augustine)

In 1884 ("Florida Reported"), the first portland cement concrete house in Florida was designed and built by Franklyn Waldo Smith in St. Augustine. The concrete was a mixture of portland cement, coquina shell and water (Pitts 1957).

While on a trip to Spain in 1882, Smith decided to design and build a winter home adopting the architecture of Moorish palaces found in Spain, Tangiers and Algiers. Observing the use of concrete for the construction of a chateau on Lake Geneva, and Smith's respect for the durability of Roman concrete structures, led him to decide to employ this new construction material. Upon his return to the United States, Smith and a Boston mason began experimenting with concrete mixtures of portland cement and coquina aggregate. With knowledge gained and adopting forming methods used by the Spanish, he began construction (Smith 1890, pp.39-44).

Walls were formed by setting ten-inch wide planks on edge, forming a trough into which a wet mixture of concrete was poured. In two days, the concrete had hardened sufficiently to allow raising of

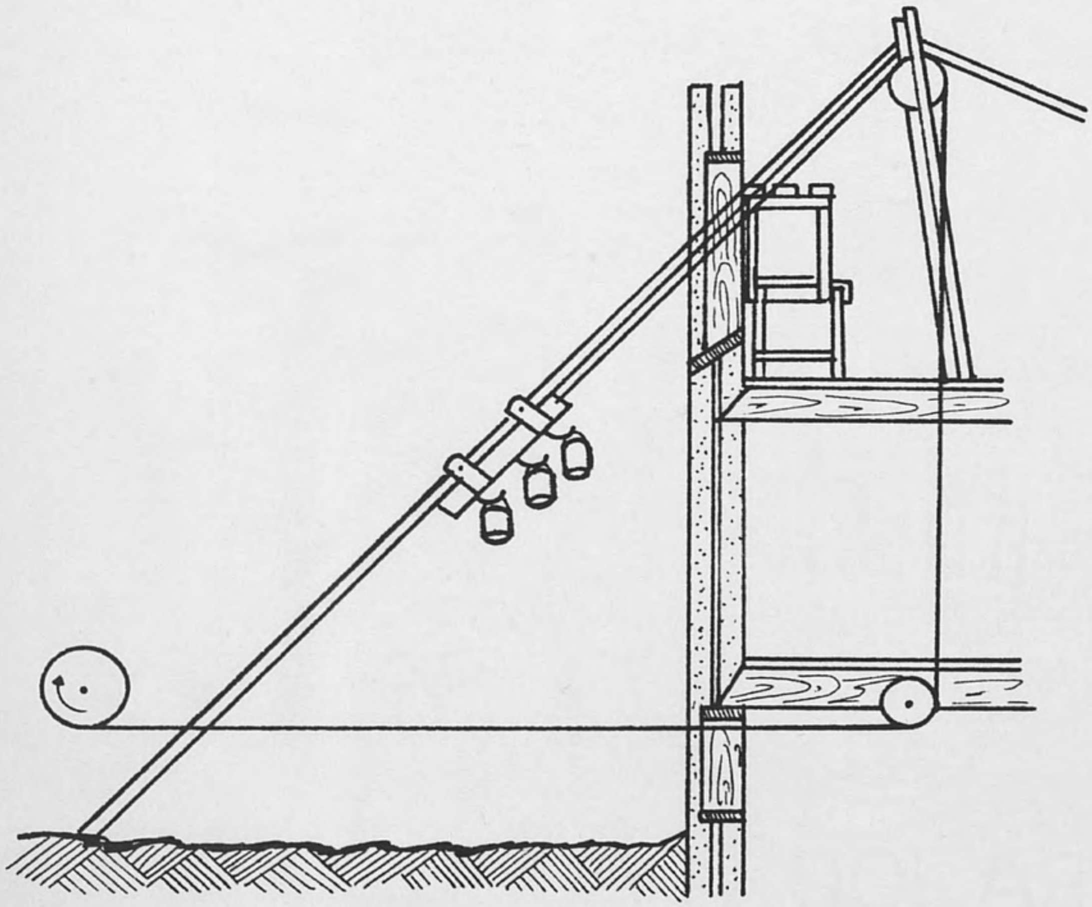


Figure 3. Inclined cableway conveyor for handling pails of concrete. (Redrawn and adapted from Gilbert 1917, p.30)

the forms and another course poured. Arches were reinforced and anchored to the walls with round iron rods. To prevent moisture migration, the outer walls were cored with an air-chamber by a board buried in the concrete during pouring and then raised, like a boat's centerboard, before the concrete set. In thirty days "the walls were as hard as any building stone, and in a year as defiant of a drill as granite" (Smith 1890, pp.44-45).

Smith's success with the Villa Zorayda gained Henry Flagler's attention, who chose this "new" material for use in constructing the Ponce de Leon Hotel (Flagler 1949).

Ponce de Leon Hotel (St. Augustine)

In May, 1885, Henry Flagler, the millionaire oil magnate, returned to St. Augustine with a young New York architect, Thomas Hastings, with the intentions to have constructed a resort hotel (Martin 1949, p.108). Chosen because of Flagler's long friendship with Hasting's father (Graham 1975, p.3), Hastings and another young architect, John M. Carrere, with no major achievements to their credit, became involved with one of the first major concrete projects in the United States, one that would establish a Spanish Renaissance theme in American architecture (Martin 1949, p.118).

James A. McGuire and Joseph E. McDonald, transplanted New England contractors, constructed the hotel (Martin 1949, p.116). The superintendent of concrete construction was William Kennish of New York. The architect's representative at the site was John W. Ingle (Carrere and Hastings 1887).

Excavation for the hotel began on December 1, 1885, and construction was completed on May 30, 1887, at a cost of $2,500,000 (Martin 1949, pp.114-117).

The concrete used in the foundation was a mixture of one part cement, one part sand and two parts coquina (1:1:2) mined from Anastasia Island. The walls were constructed of a mixture of one part cement, two parts sand and five parts coquina (1:2:5). The concrete was non-reinforced except for iron reinforcement placed in the concrete over the arches (Graham 1975, p.4).

The four-foot thick walls were cast monolithically. The state-of-the-art of concrete placement during that period was to use a very dry mix. If not tramped carefully, honeycombing resulted in low strength concrete. Twelve hundred Negroes were employed to tramp the mixture to prevent honeycombing (Martin 1949, p.115).

This magnificent structure is still in use today and is the home of Flagler College.

Casa Monica Hotel (St. Augustine)

Completed around 1887, the Casa Monica, a hotel of Spanish and Hispano-Mooresque forms, was designed and constructed by Franklyn W. Smith applying knowledge that he had gained from constructing the Villa Zorayda. Departing from previous mix designs, sea sand from the harbor was used for the bulk of the aggregate with approximately one-tenth coquina. The resulting concrete was more dense and possessed a more uniform color than the concrete used in building the Ponce de Leon (Smith 1890, p.45).

It opened within days of the opening of the Ponce de Leon and within a year was purchased by Henry Flagler and renamed the Cordova. It never achieved the success of the Ponce de Leon and stood empty in 1920 (Graham 1975, pp.6-7).

Alcazar Hotel and Casino (St. Augustine)

Completed in 1888, financed by Flagler, construction of the Alcazar began soon after construction was started on the Ponce de Leon. Built of coquina aggregate concrete with the same Spanish Renaissance theme of the Ponce de Leon, the same workers labored alternately on both hotels ("The Alcazar Hotel and the Lightner Museum" 1975).

Built to appeal to the entire public by offering cheaper rates than the Ponce de Leon, the Alcazar became very popular. To provide space for indoor recreational activities for all of Flagler's hotels, the Casino was added directly behind the Alcazar. Though implied by name, the Casino offered no gambling, but was a gymnasium-health spa with bowling, billards and tennis ("The Alcazar Hotel and the Lightner Museum" 1975).

The portland cement used in the Alcazar, Casino, Ponce de Leon and Casa Monica was supplied by Baetjer and Meyerstein who imported Hanover Cement from New York. In late 1887, prior to the completion of the Alcazar and Casino, a total of 60,000 barrels of cement had been used ("Carrere and Hasting" 1887).

Lyon Building (St. Augustine)

Constructed of the Moorish Revival style, the Lyon Building was begun by the contractor, S. Bangs Mance, in 1886. It was constructed of poured portland cement concrete with two foot thick walls and four foot wide footings. The interior floors are a foot-and-a-half thick ("Downtown Landmark Getting Uplift" 1982).

Warden Castle (St. Augustine)

In 1887, Warden Castle was built by the St. Augustine Improvement Company whose financial director, William Warden, was a partner of Henry Flagler and John D. Rockfeller in Standard Oil. Constructed of poured portland cement concrete, it was designed in Moorish Revival style characterized by battlements along the top, massive chimneys and a series of rose windows ("Warden Castle").

The building was used as a residence until the 1930's, during which it stood vacant. In 1941, it was purchased by Norton Baskin who opened it as the Castle Warden Hotel. Sold in 1946 to Daniel Crawford, Jr., it continued in use as a hotel until 1950, when it became the home of Ripley's Believe It or Not Museum ("Warden Castle").

Villa Serena (Miami)

In 1911 William Jenings Byran, had built a reinforced concrete, two-story house of Spanish architecture at 3115 Brickell Avenue in Miami. The sturdy construction survived the devastating hurricane that struck Miami in 1926 (Dunn 1974, p.73).

Byran was a tremendously talented salesman who was paid $50,000 a year to speak to prospective land buyers at the Venetian Pool in Coral Gables. His most quoted saying, which characterized the times, was "You can wake up in the morning and tell the biggest lie you can think about in the future of Coral Gables and before you go to bed at night, you will be ashamed of your modesty" (Dunn 1974, p.73).

Casa Marina Hotel (Key West)

The Casa Marina Hotel was built in Key West immediately following World War I. Constructed of poured portland cement concrete, it had been planned by Henry Flagler before his death in 1913 (White 1959, p.88).

The use of concrete was a distinct change from the wooden buildings of Caribbean style so common to the area. It was to begin a trend in the Keys that resulted in many new homes being built of poured concrete or concrete masonry (White 1959, p.88).

Sulfur Springs Park (Tampa)

A popular picnic area with local residents since the 1880's, Sulfur Springs was used by developer Josiah Richardson to attract tourists to the area as potential land buyers. By 1920, the spring fed pool was enclosed by a circular concrete retaining wall. In 1925, construction of the Sulfur Springs Arcade was initiated. This concrete structure was listed in Ripley's Believe It or Not as a "complete town under one roof." Torn down in 1976 to provide parking for a near-by dogtrack, a two-story octagonal shaped gazebo constructed of reinforced concrete remains in the area ("Sulfur Springs park").

Also remaining is an unique 225 feet tall poured-in-place water tower built from 1925 to 1926. The engineer, Groover Poole, designed the structure to hold approximately 150,000 gallons of water. Living quarters were provided on the second story for the tower operator and his family ("Sulfur Springs Park").

Florida's "Boom" Hotels

Florida entered the third decade of the twentieth century on the verge of one of the most accelerated growth rates ever to be experienced. The construction of a statewide system of roads in the twenties would provide the access to new and less developed places for people tired of the urbanized, industrialized areas. Traveling became popular and the Florida countryside was dotted with Tin Can Tourist Camps due to the shortage of housing (Tebeau 1971, pp.383-385). Before the speculation bubble "burst" in 1926, and the depression that hit in 1929, several concrete and masonry hotels and hotel-apartments were built throughout Florida. Taken from Taylor and Bliss, the following hotels were built prior to 1928.

Julia Tuttle Apartments (Miami)

This six-story, ninety-room structure is reinforced concrete with a stucco exterior trimmed with cast stone.

Roney Plaza (Miami Beach)

One of Florida's largest resort hotels when built, this hotel designed by Schultze and Weaver, Architects, contained approximately 300 rooms. It was constructed of concrete with an exterior of stucco and stone.

Manatee River Hotel (Bradenton)

Constructed of a reinforced concrete frame with tile floor slabs and stuccoed tile exterior walls, this pile-supported, eight-story, 165 suite hotel cost approximately 55 cents per cubic foot to build.

The architect, J. Harold MacDowell, designed the unique feature of disappearing beds so that the bedrooms could also serve as living rooms.

Dallas Park Apartment Hotel (Miami Beach)

Designed by Robertson and Patterson, Architects, this reinforced concrete from building with walls of interlocking hollow tile and tinted stucco and composition stone trim exterior was completed in January 1925 at a cost of $800,000.

Hotel Alcazar (Miami)

This thirteen-story hotel was constructed with a reinforced concrete frame at a total cost of $1,025,000 or $4,100 per room. The exterior was stucco with composition stone trimming. It was completed in February, 1926.

Hotel Kelly (Gainesville)

Construction on this reinforced concrete frame structure was suspended when the bust of 1926 came. It was completed several years later after being turned over to the University of Florida. Renamed the Seagle Building, it housed the Florida State Museum for many years (Smiley 1974, p.183).

Many hotels built during the early part of the twentieth century were of non-fireproof construction. A number of holocausts turned the public strongly against such inflammable structures resulting in a marked difference in the rental rates that could be charged by hotels of fireproof reinforced concrete (Taylor and Bliss 1928, p.149).

Conrad Shuck House (Bartow)

Construction began on this structurally reinforced concrete house on Mann Road in Bartow in 1923. After 15 years of work by the builder, Conrad Shuck, the lack of funds during the depression years forced him to stop construction. The four-story house has concrete walls 18 inches thick at the base tapering to 12 inches at the roof. Broken tile and glass was embedded in the concrete of outer walkways. Eventually the house was completed and what was once Bartow's "Crazy House" is now Bartow's "Wonder House" (Gessner 1975).

Hurricane Shelters (Florida Keys)

The devastating hurricane that struck Key West on Labor Day, 1935, resulted in the lose of approximately four hundred lives. At least 190 were World War I veterans on work relief placed there by the Federal Government to work on the Overseas Highway (Griswold 1965, p.68).

In 1938, the Works Progress Administration constructed two poured concrete hurricane shelters in the Florida Keys. One was located on the lower end of Key Largo and the other on Upper Matecumbe Key. The single-story $20,000 buildings were designed for normal use as schools, but were equipped with kitchens, water storage and sanitation facilities for emergency use (see Figure 4) ("Hurricane Shelters in Florida" 1938, p.735).

Designed to resist a live load of 150 psf with an isolated impact resistance of 250 psf for flying debris, walls were twelve inches thick of poured concrete reinforced with 0.5 inch diameter steel rods

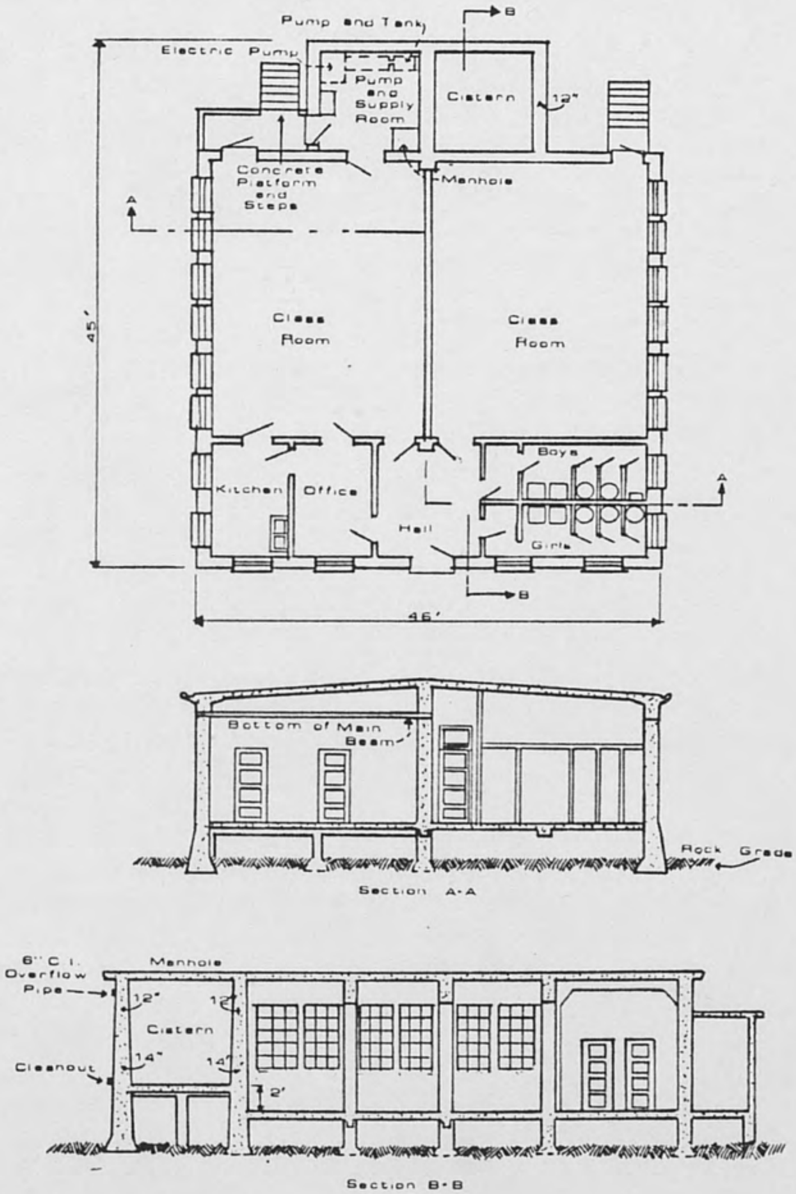


Figure 4. Florida hurricane shelter. (Redrawn and adapted from "Hurricane Shelters in Florida" 1938)

spaced six inches on centers vertically and horizontally placed four inches from the inside face of the wall. The vertical steel reinforcing was bent at the top and the walls and roof were poured monolithically from the ground to the roof ("Hurricane Shelters in Florida" 1938, p.735).

To prevent water from washing beneath the floor, walls were extended into the supporting limestone around the perimeter of the building. The walls and intermediate columns rested in trenches or holes that extended one to two feet into the limestone with a "keystone" cross-section to resist uplift. Walls were tied into the six inch thick concrete floor with keyed construction joints. The floor and roof were designed to resist 100 psf live load ("Hurricane Shelters in Florida" 1938, p.735).

Concrete in the structure was specified to have a compressive strength of 3000 psi and steel reinforcing 18,000 psi ("Hurricane Shelters" in Florida" 1938, p.735).

Concrete Bridges

Until the development of materials capable of resisting tensile stresses, bridges were designed so that supported loads were carried by structures capable of resisting compression stresses. The most efficient of such bridging structures is the arch developed by the Romans and used extensively to carry Rome's water systems and highways over valleys and gorges.

The first portland cement concrete arch bridge was the Grand Maite Bridge built in 1869 as part of the Paris waterworks system. The first in the United States spanned thirty-one feet and was built in 1871 in Brooklyn, New York. Ernest L. Ransome designed and built the first reinforced concrete arch bridge in 1889 in San Francisco (Draffin 1976, p.35).

Fritz von Emperger introduced to the United States the Melan system which consisted of reinforcing concrete with structural shapes. He designed and built a number of reinforced concrete bridges beginning in 1894, overcoming difficulties encountered by the inconsistency of American cement and lack of experienced workers (Draffin 1976, p.35).

Being cheaper than all steel bridges, reinforced concrete dominated short span bridging during the early decades of the twentieth century (Steinman 1957, p.271).

Florida East Coast Railway's Key West Extension

One of the greatest bridge building feats in history was part of Florida's East Coast Railway's Key West Extension. Beginning in April, 1905 from Homestead (Culter 1923, p.68), it was completed January 21, 1912 in Key West, at an estimated cost of $27,000,000 (Parks 1968, pp.26-38).

It is difficult to surmise Henry Flagler's reason for building the Key West Extension. Could it have been the potential profit from importing pineapples, sugar and oranges from Cuba? Profit added to the coffers of a man possessing more wealth than he could spend in his lifetime. Could it have been an attempt to ease the conscience of an old man accused of unfairly monopolizing the oil industry in American by building the country access to her strategic naval base at Key West, or could it have been the desire for profit from another war like the recently fought Spanish-American War?

At the time, Key West was the only deep water port on the east coast to as far north as Jacksonville (Kendrick 1964, p.141); thus, an invaluable outfitting harbor for ships entering or leaving the Gulf of Mexico. Whatever the motive, Flagler had the resources; what he needed was the engineering ability.

Disappointed with the response of only a single "cost-plus" contract to build the railway, Flagler decided that the railroad would be built by his own railroad company. To lead such an undertaking, Flagler hired Joseph C. Meredith, an engineer with an established reputation with experience on numerous projects, the most recent having been the Panama Canal. To assist Meredith, W.J. Krome, who had supervised preliminary survey work, was appointed his first assistant. E. Ben Carter was chief engineer; P.L. Wilson, C.S. Coe and Ernst Cotton were division engineers; R.W. Carter, bridge engineer and Edward Sheeran, general foreman. Meredith would not see the project completed, dying in April, 1909, with Krome assuming the role of chief engineer (Culter et al. 1923, pp.68,209).

An estimated 800,000 pounds of German and American cement were used to make 461,000 cubic yards of concrete in construction of piers and viaducts. Because of its consistent quality, only German Alsen cement was used below water level using a 1:2:4 mix design. A 1:3:5 mix was used in the viaducts. Thirty-eight million pounds of structural steel and 2,000 tons of 3/4-inch Ransome steel reinforcement were also used. Fresh water for concrete was scarce, consequently sea water was used during latter parts of construction, having been used initially in parts of the Long Key Viaduct ("Key West Extension - Florida East Coast Railway").

To place such an enormous quantity of material, Flagler purchased eight concrete mixers for work over water, two concrete mixers for work on land, nine floating pile drivers, two track pile drivers, eight stern-wheet Mississippi River steamers, twenty-seven launches and numerous other pieces of equipment (Culter et al. 1923, p.70).

The first concrete bridge off the mainland crossed Cards Sound to Key Largo and the construction more closely resembled that of ordinary railroad building. The first of three long viaducts began with Long Key Viaduct, 10,446 feet of 50 foot arches of the only reinforced concrete structures in the project ("Key West Extension-Florida East Coast Railway").

Shortly after construction began on Long Key Viaduct in 1906, a hurricane hit with winds in excess of 100 miles per hour. A total of 130 men died (Parks 1968, p.10). It was the first of three hurricanes that would delay and alter the course of the railroad.

By 1908, Flagler's engineers were working on Seven Mile Bridge. Divided into four segments, it was actually nine miles in length. The first three segments, Knights Key Bridge, Pigeon Key Bridge and Moser Channel Bridge were spanned by steel girders on concrete piers. A 253 foot swinging span over Moser Channel was included to allow the passage of ships between the Gulf and the Atlantic. The last segment, Pacet Channel Viaduct, was comprised of arches similiar to Long Key Viaduct (Parks 1968, p.17).

A second hurricane in 1909 washed out 40 miles of embankment and extended the completion date an additional two years (Parks 1968, p.20). Originally 6 miles of open water was to be bridged, with shallow water to be spanned with wooden trestles filled with rock and earth. Engineers had assumed that the quantity of tidal water flowing from the sound through the open arches and piers into the ocean would be no greater than the quantity that had entered the same passageway. This assumption was proved wrong when water backed up into Biscayne Bay by hurricane winds retreated with such scouring force that 10 ton boulders were carried out to sea. Consequently, the length of open water spanned by bridges would be increased from 6 to 18 miles (Culter et al. 1923, p.69).

Advancing southward, the Bahia Honda Bridge spanned water 35 feet deep, the deepest to be encountered. Concrete arch viaducts dovetailed at the joints to allow for expansion and contraction, alternated with arched steel trusses. Below Big Pine Key, the Niles Channel Bridge, approximately a mile long, carried rail toward Pine, Kemp, Bow, Boca Chica, and the Bahia Honda Bridge, the last major viaduct before reaching Key West (Parks 1968, p.25).

The "Extension Special" left Miami on January 22, 1912, carrying Henry Flagler to Key West. He would die 14 months later. The line never carried enough cargo to be profitable and went into receivership during the depression (Parks 1968, pp.26-38).

The devastating hurricane of 1935 destroyed large sections of the railway and its right-of-way was sold to become part of the Overseas Highway (Kendrick 1964, p.139).

Lafayette Bridge (Tampa)

One of the finest concrete structures in the South at the time it was constructed, the only other bridge like it spanned the Thames River. Of Bascule design, this reinforced concrete bridge was opened in 1914 at a cost of $300,000 (Cutler et al. 1923, p.325).

The draw spans had such perfect balance that "a small boy could lift it." Weather conditions would alter the center of gravity of the cantilever draw spans, so "mechanical contrivances" allowed the bridge tender to adjust the counter balance to keep the spans balanced (Cutler et al. 1923, p.325).

Gandy Bridge (Tampa)

When George Gandy first visited St. Petersburg in 1902, the shortest route from Tampa was around the edge of Tampa Bay, a distance of 43 miles. In 1915, Gandy decided to construct a bridge across Tampa Bay, shortening the distance to 19 miles. Applying to the War Department in 1917 for permission to span navigable waters, rival interest delayed issuance of permission for 9 months (Grismer 1924, p.160).

World War I made it impossible for Gandy's engineers to secure necessary building materials and after the Armistice, material prices were too high. Finally in 1922, 200,000 shares of preferred stock and 250,000 shares of common stock were sold to finance construction of the toll bridge (Grismer 1924, pp.161-162).

Construction began on November 22, 1922, with the dredging of the first of 3,000,000 cubic yards of sand for the causeways. Casting of concrete piles to support the 24 foot wide, 2 1/2 mile long reinforced concrete bridge was begun on May 15, 1923 (Grismer 1924, p.162). The bridge was offically opened in November, 1924 (Kendrick 1964, p.67), in time for St. Petersburg to participate in the 1920's land boom.

CHAPTER VI

MISCELLANEOUS

By the late 1920's, concrete had become a popular building material for buildings and bridges. Concrete was also used to a lesser extent for ships and highways. The shortage of ships experienced during World War I resulted in an attempt to build reinforced concrete ships, and while the majority of Florida's early roads were clay or asphalt, concrete was used for roadway construction at scattered locations throughout the state.

Concrete Ships

By the end of 1917, German submarines had sunk 8,000,000 tons of Allied shipping (Brinton II 1960, p.397). To replace such losses, America was constructing ships as quickly as possible, using every applicable material.

By 1919, the United States Shipping Board Emergency Fleet Corporation was overseeing the construction of 14 reinforced concrete ships of 5 different types. Two 7500 ton D.W. Type 70 oil tankers (see Figure 5), requiring 2,800 cubic yards of concrete each, were being constructed by A. Bentley and Sons Company of Toledo, Ohio at a shipyard in Jacksonville, along the St. Johns River (Wig 1919, pp.241-267).

These reinforced concrete ships were comprised of walls, floors and columns similar to a building, but unlike a building, the concrete ships had to be constructed on a temporary foundation requir-

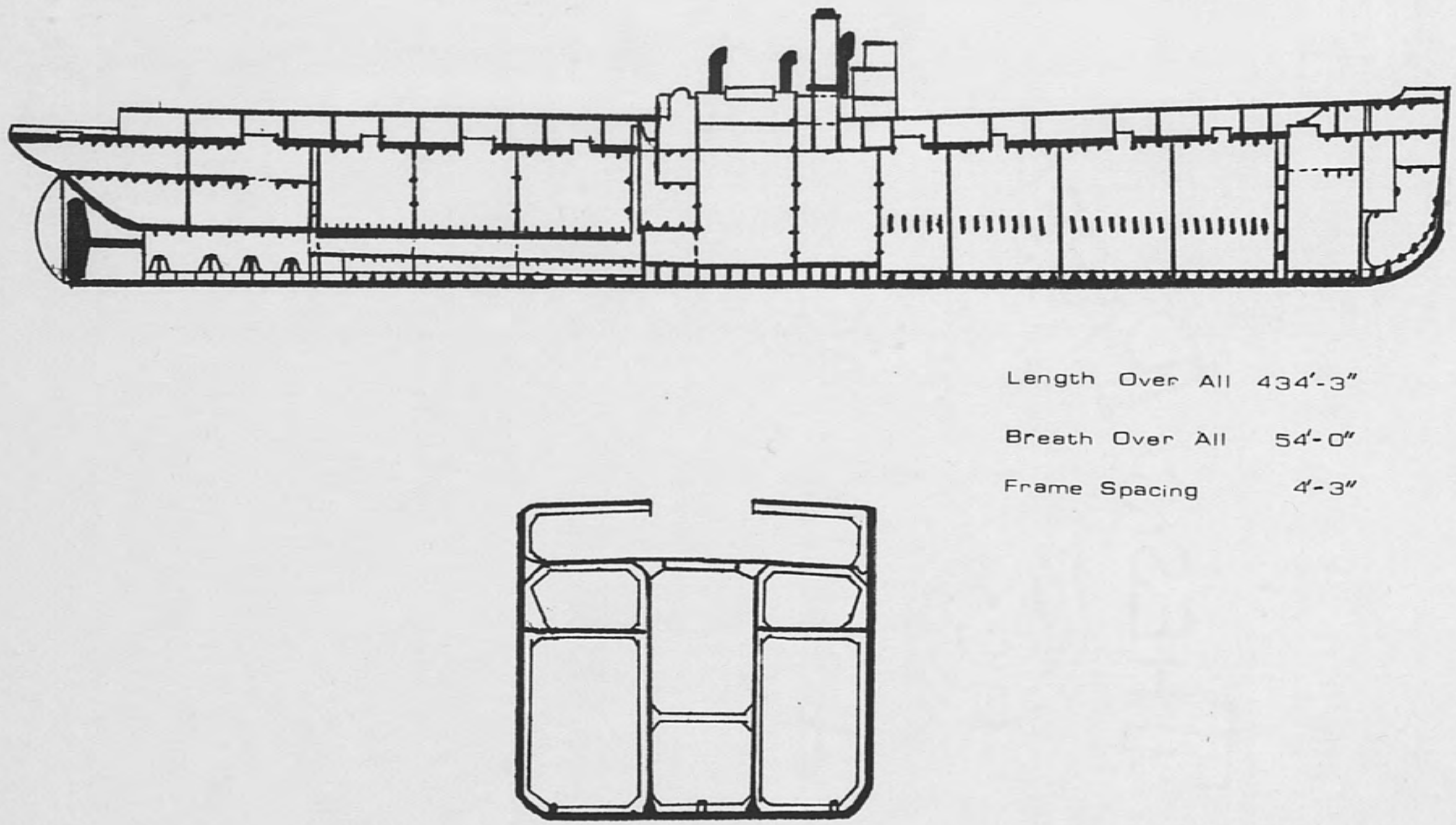


Figure 5. 7500 ton D.W. Type 70 oil tanker. (Redrawn and adapted from Wig 1919)

ing innovative forming techniques that provided great rigidity and conformed to irregular curves and shapes with exacting dimensions. Reinforcement steel bending and placement followed very small tolerances (Wig 1919, p.242).

Concrete was mixed at 1:1:1 to 1:1:2 ratio and specified to have a minimum 28 day compressive strength of 4,000 psi. High grade portland cement was required with specifications that 90 percent pass the number 200 mesh sieve. To produce a lightweight concrete of 105 to 120 pcf expanded clay aggregate was developed. Fine aggregate, obtained by crushing the expanded clay, was blended in a 1:1 to 1:2 ratio of fine to coarse aggregate (Wig 1919, pp.263-264).

Concrete was transported by bottom dump buckets suspended from derricks from mixers to mortar boxes from which it was shoveled or "pailed" into forms which were vibrated with small air hammers to prevent honeycombing of the stiff concrete mixes. Crews placed concrete continuously for 50 to 100 hours, generally working from the ends toward the middle, meeting crews working from the middle toward the end. Watertight construction joints were made by chipping and roughing hardened concrete prior to joining with fresh concrete, with grouting seldom required (Wig 1919, pp.264-268).

Total cost for the concrete hulls alone was $600,000 to $700,000 with outfitting estimated to cost another $600,000 (Wig 1919, p.276).

If properly designed and constructed, concrete ships would resist normal stresses to which ships at sea are subjected. But, they had one inherent weakness. The 4 inch shell hull would not resist local impact of moderate intensity (Wig 1919, p.285). Though cost and cargo carrying capacity of concrete ships was competitive with wood and steel hull ships, their performance did not justify their continued construction.

Concrete Roads

The first concrete road was built in 1838 from London to Holyhead, England. The 6 inch thick, 18 foot wide pavement was constructed with 1 part Parker Roman cement to 8 parts washed gravel and sand ("Landmarks in the History of Concrete" 1981, p.1030).

In 1891, the first concrete pavement in the United States was laid by George Bartholomew, Jr. in Bellfountaine, Ohio. A 10 foot wide, 220 foot strip comprised one side of a public square with the remaining four sides completed between 1893 to 1894. Designed largely from sidewalk experience, the 6 inch thick pavement was laid in two courses. The bottom 4 inches was a 1:5 mix and the top 2 inches was a 3:5 mix (Bartholomew 1941, pp.297-299).

On October 10, 1908, an 11 mile race course with superelevated curves was opened for William K. Vanderbilt Jr.'s automobile races. The 5 inch thick, 24 foot wide portland cement concrete pavement was reinforced with steel-wire-mesh (Rose 1976, p.85).

In 1909, the first public concrete roadway was built in Wayne County, Michigan. It consisted of three experimental strips of pavement totaling a distance of 2 miles (Draffin 1976, p.37).

Between 1909 and 1918, there was a gradual increase in the construction of concrete pavements. The popularity of portland cement concrete increased noticeable after 1919 due to the invention of the paving machine, improved methods of design, tremendous increase in the use of the automobile and an enlarged advertising program by the Portland Cement Association (Draffin 1976, pp.37-38).

Florida's Concrete Roads

According to A. R. Brickler, past district engineer for the Portland Cement Association, the first portland cement concrete strip in Florida was a ramp built by the United States Navy in Key West in 1880 (Kendrick 1964, p.218).

The first complete mile of concrete road was built in 1918 at Fellsmere in Indian River County. Located northwest of Vero Beach, it is now part of State Road 512. In 1919, 3 miles of concrete road were built in DeSoto County and 4 miles added in 1921 (Kendrick 1964, p.218).

In 1923, Florida possessed the nineth longest concrete road in the United States. Beginning 5 miles west of the center of Jacksonville, this 43 mile roadway extended westward as part of U.S. 90 to the Columbia County line. Cement from Richard City, Tennessee; sand from Lumber City, Georgia; and gravel from South Carolina were used in a 1:2:4 mix (Kendrick 1964, p.218).

In 1924, a 10 mile section of concrete roadway was built north of Pensacola. An inexperienced contractor left the bonding company to finish the job, who hired Lawrence Construction Company to complete the project (Kendrick 1964, p.207).

In 1926, 12.7 miles of concrete pavement were laid in Suwannee County. In Madison County, 16 miles were laid for \$464,300 and 14.96 miles in St. Johns County for \$433,000 (Kendrick 1964, p.87).

In 1927, 10 miles of concrete pavement were constructed by Lawrence Construction Company north of Panama City on U.S. 231 (Kendrick 1964, p.207).

Much of the growth in road building was due to financial aid from the Federal Government. To qualify for Federal funds, a state had to match funds dollar for dollar and have an active state highway department. Consequently, the Florida State Road Department was created by State Statue in 1915. William F. Cocke, a division engineer the State Highway Commission of Virginia, was the first commissioner at an annual salary of $3,000 (Kendrick 1964, pp.8-11).

In 1917, the Legislature established the Convict Road Force of the State Road Department. Prisoners worked from daylight to dark, eating corn bread and beans by lantern light. Strict discipline was the rule and leg irons were worn until the 1940's. Sweat boxes were eliminated in 1958. Having been a significant part of the State Road Department, changing political attitudes in the 1960's would reduce its role to only a fraction of the support once provided (Kendrick 1964, pp.43-55).

<u>The Overseas Highway</u>

Between 1922 and 1928, Monroe County spent approximately $3,000,000 constructing a highway from the Florida mainland to Key West, roughly paralleling the Florida East Coast Railway Extension. Car ferries shuttled automobiles between a 60 mile segment from Florida City to Lower Matecumbe Key and a 40 mile segment from No Name Key to Key West. Unlike the sturdy railroad bridges of concrete and iron, the highway bridges were of light load capacity timber construction (Kendrick 1964, p.139).

Roosevelt's New Deal Administration established a Federal Emergency Relief Administration camp on the mainland and three camps in the Keys. These workers, comprised of jobless World War I veterans, worked on preliminaries of closing the unbridged gap (Griswold 1965, p.65).

One hundred and ninety of those veterans died in the devastating Labor Day hurricane in 1935, when an evacuation train supposedly stationed in Homestead was not there. Delay over assembling a second evacuation train's operating crew on holiday in Miami proved costly. The lowest atmospheric pressure reading ever recorded in the Northern Hemisphere and resulting winds reportedly in excess of 250 mph caused a loss of approximately 400 lives and destroyed large sections of the highway and previously abandoned railroad (Griswold 1965, p.68).

The Overseas Road and Toll Bridge District immediately took steps to secure property rights and railroad right-of-way which would become part of the Overseas Highway for $640,000. The highway was completed in 1944 (Kendrick 1964, p.139).

Soil-Cement

Soil-cement is a mixture of cement, soil and water, with the cement added to the soil or earth to provide additional strenth and stability. The first use of soil-cement can be traced to records left by Roman engineers. A typical Roman highway and one of the finest, was the Via Appia which connected Rome with Brindisi. Using pozzolona lime as cement, this 4.5 meter wide roadway was constructed in five layers. The surface layer of crushed lava covered a course of granite stone followed by a soil-cement layer. The bottom-most layers were of small stones on compacted earth (Overman 1968, pp.38-41).

Modern soil-cement

The first recorded road projects of soil-cement were built in South Dakota, Iowa, Ohio, California and Texas in the early 1930's. From 1933 to 1935, the South Carolina Highway Department did significant work with soil-cement. In 1935, the Portland Cement Association performed extensive research on soil-cement mix design resulting in the adoption of standard test methods for soil-cement mixtures by the American Society of Testing and Materials in 1944 (Portland Cement Association 1959).

Soil-cement in Florida

According to Larry L. Smith, with the Department of Transportation in Gainesville, the first section of soil-cement roadway base material was laid sometime between 1938 to 1940. The roadway is located east-south-east of Tallahassee as part of State Road 259 between Waukeenah and Thomas City.

CHAPTER VII

MASONRY AND BLOCKS

Masonry is essentially an assembly of building blocks set in a cement mortar. Early masonry structures were constructed of natural building stones whose physical characteristics varied depending upon the stone's constituents and the physical forces that acted upon it. Portland cement allowed the builder to manufacture a "stone" or block which possessed consistent physical properties.

Masonry

Some of the earliest masonry structures in the United States were built of coquina rock in Florida. This rock, discovered by the Spanish and found in abundance on Anastasia Island just east of St. Augustine, became a popular building stone of the Spanish settlers and early plantation builders in Florida.

Coquina Masonry

The first clearly documented masonry construction in Florida was a coquina stone powder magazine built between 1596 and 1598 in St. Augustine (Manucy 1978, p.17).

Castillo de San Marcos

Though not abundant in riches, Florida was an important way station in Spain's commercial route which carried gold and silver from Peru and Mexico. In 1671, Sergeant Major Don Manuel de Cendoya arrived in St. Augustine with his engineer, Ignacio Daza, and skilled lime-burners and masons from Cuba, with orders to construct a permanent fort (Arana 1977, pp.9-17).

By the Spring of 1672, there were 7,000 bushels of lime and large quantities of coquina stone stockpiled. Though not always willing, Indians from three nations; the Guale, from Coastal Georgia; Timucua, from east of the Aucilla River and the Apalachee, from between the Aucilla and Apalachicola Rivers, were employed at 20 cents a day. They were joined with a few convicts, who had been caught smuggling, and black slaves (Arana 1977, pp.19-20).

The engineer, Daza, laid the first stone November 9, 1672, as part of two courses of stone placed in a 17 foot wide, 5 foot deep foundation trench. The foundation supported a 20 foot tall wall which tapered from a 13 foot wide cross-section at the base to 9 feet at the top. Construction proceeded slowly due to lack of supplies and labor, and when Daza died in 1673 a replacement engineer was not present until Ensign Don Juan de Ciscara arrived for a brief stay in 1680. Numerous construction flaws had been incorporated into the fort since Daza's death, but corrections were made and the fort completed in August 1695. The cost of construction was 138,375 pesos or about $220,000 much of which was "borrowed" from Spanish soldiers pay, which was never repaid (Arana 1977, pp.26-36).

Coquina Masonry on Florida's Plantations

Many of Florida's plantation structures built in the late 1700's and early 1800's were coquina masonry, often with tabby floors.

A popular use of coquina block was for support of machinery such as sugar mills and cotton mills.

One of Florida's first plantations was the Carrickfergus Plantation bordering the Tomoka River in Volusia County. This 1,414 acre plantation settled in 1816 by John Addison, descendant of an aristocratic North Carolina family, had slave quarters with tabby floor construction. Remains exist of a 15 foot long, 12 foot wide coquina block house constructed around 1836 by South Carolina troops as a mini-fort, Fort McRae, during the Seminole Indian Wars (Stanton 1949).

The use of coquina block as a major building material diminished with the passing of Florida's plantation system at the Civil War's end. Tourism would spur the economy of Florida in the 1880's and the popularity of manufactured portland cement building blocks would reduce the use of coquina stone to ornamental applications.

Manufactured Concrete Building Blocks

In 1832, in England, Ranger patented a method for producing solid concrete blocks. In 1850, Joseph Gibbs received a patent for solid concrete walls which used hollow concrete block filled with concrete (Bennett 1981, p.23).

The first structure of man-made concrete block in the United States was a house constructed by G.A. Ward in 1837 on Staten Island. Ward molded the concrete blocks at the site (Collins 1959, p.56). In 1866, C.S. Hutchinson was granted a patent for a hollow concrete block wall with vertical voids (Bennett 1981, p.23). In 1895, the first machine to make concrete masonry units was marketed (Portland Cement

Association 1975, p.26), and by 1924, affordable machines were available (Bennett 1981, p.23).

Manufactured concrete building blocks in Florida

Railway built during the nineteenth century provided Florida a system by which materials could be easily moved. The automobile and highways built early in the twentieth century were beginning to transmute Florida's quiescent society.

In 1902 more homes were built in Florida, in proportion to her population, than in any other State (Dau 1975, p.303). Florida's population increased from 528,542 in 1900 to 1,263,549 in 1925. During Florida's boom from 1920 to 1925, the population increased by 300,000 (Cox and Dovell 1974, p.162).

Manufactured concrete blocks provided Florida builders with an ideal material for a sunny, hot and humid environment which offered ideal conditions for termites and fungi that cause wood damage and decay.

To provide a blending of this new man-made building material into Florida's landscape, a style of architecture to compliment the thick, rough walls was needed. This need was satisfied by the adoption of a Spanish-Mexican style. Possessing an almost austere simplicity, this sturdy, straight forward style was easily adapted to Florida's sunny climate.

To promote concrete masonry, the Portland Cement Association assembled a collection of floor plans with information on estimating cost and construction procedures (see Figure 6). Information on

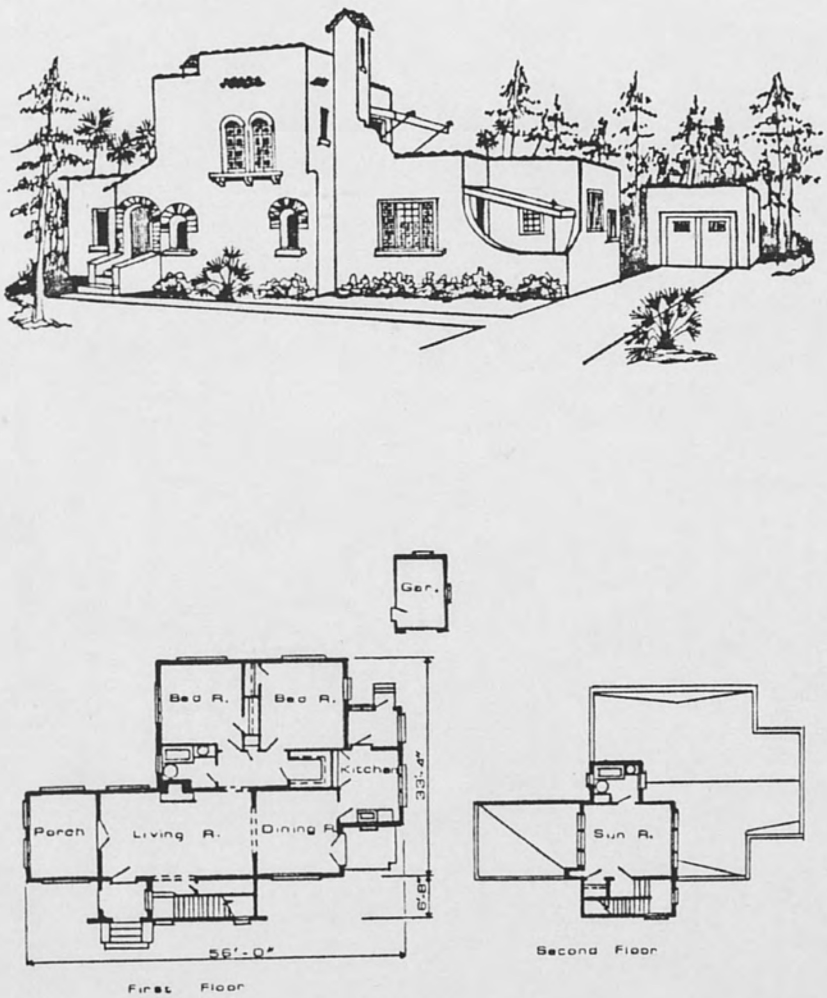


Figure 6. Coral Gables masonry house. (Redrawn and adapted from Plans for Concrete Houses 1925)

estimating and construction procedures was included for a $5.00 cost (Portland Cement Association 1925).

Florida's land boom of the 1920's would dot Florida's countryside with subdivisions before the collapse in 1926. Followed by the Depression beginning in 1929, it would be years before Florida would again experience the record growth rate of the 1920's.

William A. Morrison House (Tampa)

Of contrasting style to the popular Spanish-Mexican theme of houses built of concrete block in the 1900's, this three story Italian Villa style house, built between 1879 and 1881, is the oldest standing residence in Tampa. When constructed, it employed the first use of concrete block for a private home in the Tampa area. The house is located at 850 South Newport Avenue and is currently used as a private residence ("Morrison").

The concrete blocks used were cast by hand at the construction site under the supervision of F.W. Colby of Phillipsburg, Kansas. Colby was the patentee of a process for manufacturing an artificial building block which combined lime, sand, cement and "certain chemicals." Though more expensive than the standard wooden house, Colby claimed that for durability and safety against fire, "in the end" the concrete block house would be cheaper (Tampa, Sunland Tribune).

CHAPTER VIII

BUILDING CODES, SPECIFICATIONS AND STANDARDS

Concrete is the only building material used to provide structural support that is made on the job. Subsequently, it presents a different and more difficult set of problems than does any other building material, especially in the establishment of codes and specifications to govern its use.

Consider that the establishment of a material standard or a model building code is by committee agreement. Committee agreement is seldom unanimous, but a compromised settlement. Add to that the fact that much of the state-of-the-art concrete design and construction is empirical and opinions from such knowledge seldom agree exactly.

The development of material standards and model building codes for cement and concrete materials was, and is, an arduous task. The introduction and acceptance of new ideas and procedures often followed an arresting pace. And while standards and codes provided guidance in an attempt to protect the safety and well-being of the public, they often delayed the development of new and better materials and safer and more efficient methods of design and construction.

In addition, producers of competitive materials endeavored to have requirements written into building codes to handicap new materials. When first introduced, restrictions on concrete buildings in

Manhattan were so strict that concrete construction was not possible (Humphrey 1924, p.37).

Portland Cement Standards and Specifications

The formulation of standards and specifications for cement in the United States was a two step process: first, the development of standard test methods; second, the adoption of reasonable values for the different properties determined by the standard tests (Draffin 1976, p.16).

The first part of this process was begun in 1884 by the American Society of Civil Engineers. The second part was begun in 1896, when no generally accepted specification for cement quality existed. Each engineer would write his own specification, resulting in numerous diverse requirements (Draffin 1976, p.16).

In 1904, the American Society of Testing and Materials jointly with the American Society of Civil Engineers, American Railway Engineering Association and the American Portland Cement manufacturers issued a set of minimum specifications for portland cement. Revised in subsequent years, the improvement in the consistency of the cement did much to increase its popularity with designers (Draffin 1976, p.17).

Design Codes

Early design codes were the product of a joint effort of representatives of several associations. Committees were composed of representatives of the American Society of Civil Engineers (ASCE), American Society for Testing and Materials (ASTM), Portland Cement Association (PCA), American Concrete Institute (ACI), American Railway Engineering Association (AREA) and the American Institute of Architects (AIA). Committees were organized in 1904, 1920 and 1930 and their final reports were issued in 1916, 1924 and 1940 respectively (Draffin 1976, p.31).

The 1916 report dealt primarily with fundamental principles of design. The 1924 report again emphasized design principles, and in addition, design details, constants and procedures were presented along with higher working stresses. The 1940 report placed emphasis on the durability of concrete and recognized new methods of placing concrete, such as mechanical vibrator, spouting, aerial-tramway and pumping. In addition, the principle of continuity and elastic frame analysis in the design of reinforced concrete structures was included and alternative methods of specifying mix proportions allowed for specification by engineer or by specified quality (Draffin 1976, p.31).

In more recent times, the task of formulating model codes related to concrete design and placement has been handled by committees comprised of members of ACI.

CHAPTER IX

ORGANIZATIONS

Several organizations provided support to advance the science of cement making and the use of concrete.

In the earliest days of cement making, the American Society of Civil Engineers (ASCE), organized in 1852, provided technical expertise and was instrumental in establishing the first specifications for cement.

In 1898, the American Society for Testing and Materials (ASTM) was founded to develop standards on the characteristics and performance of materials, products, systems and services (Lukens 1978, p.iii).

In 1902, a group of eastern cement manufacturers met to exchange ideas on improving the recovery of sacks used to package and ship cement. Realizing the value of such a meeting, the Association of Portland Cement Manufacturers was organized. In 1904 the name was changes to the Association of American Portland Cement Manufacturers which it remained until 1916, becoming the Portland Cement Association (Lesley, Lober and Bartlett 1972, pp.196-230).

In 1905, the National Association of Cement Users was organized at a convention in Indianapolis, Indiana, for the purpose of disseminating information to promote the use of portland cement. On July 2, 1913, the name was changed to the American Concrete Institute (American Concrete Institute, pp.23-24).

CHAPTER X

SUMMARY

Used first by the Romans 2000 years ago, concrete has been one of man's most durable building materials.

Early concrete structures in Florida were built of tabby, a primitive concrete made with hydraulic lime, oyster shell, sand and water. Cuban masons and limeburners brought their knowledge of lime making to Florida when recruited by the Spanish to build the Castillo de San Marcos in St. Augustine in the late 1600's. The Spanish constructed numerous homes of tabby in St. Augustine, but most were destroyed by the English during their occupation.

Tabby was used by Florida's plantation owners in the late 1700's and early 1800's, and remains of tabby plantation homes and slave quarters can be found throughout the State.

The invention and manufacture of portland cement in the late 1800's supplied the builder with a cement which produced a stronger, more durable concrete. Initially adopted because of its fire-resistant qualities, the use of portland cement concrete was limited because of lack of design knowledge, restrictive building codes, cumbersome construction techniques and lack of adequately trained workers. Only the wealthy could afford the earliest poured concrete structures.

Flagler's adoption of concrete for his hotel in St. Augustine in 1885 began a building trend in the area that produced buildings that are still in use today. His railway extension using miles of concrete viaducts from the Florida mainland to Key West stands as one of American engineers' greatest achievements.

Concrete ships were made in Jacksonville during World War I. The war and resulting industrialization brought a rapid change to America, too rapid for many, who escaped the factories and traveled to Florida to enjoy her clean, more relaxed environment.

The 1920's saw a tremendous increase in popularity of reinforced concrete structures. Extensive research by early builders, designers and industry organizations, who developed design procedures, construction techniques, building codes and material standards, made possible safe and affordable structures.

The introduction of ready-mixed concrete and mass produced concrete blocks made available to the housing industry Florida's most durable building material. Concrete masonry houses were economical and simple to construct. Florida's early subdivisions were dominated by concrete masonry homes designed with a characteristic Spanish-Mexican theme.

Concrete has played an important role in the growth and development of Florida. When used with intelligence, the designer and builder created a structure which served its owner for many, many years. And that is the ultimate triumph for a building material and the greatest reward for the designer and builder.

GLOSSARY

Argillaceous: containing clay or clay minerals.

Bascule Bridge: bridge characterized by two counterweighted supported on horizontal pivots.

Beam Strips: the division of a concrete slab into thin strips, like a beam, for the purpose of analysis.

Bending Movement: a term which quantifies the amount of work that tends to cause a member to bend.

Bottle Kiln: a furnace with a shape resembling a bottle used to burn or process materials at high temperature.

Compression Stresses: the resistance that a body exerts subjected to an action that tends to compress or shorten the body.

Coquina: small marine clam.

Coquina Rock: a concretion of coquina shells.

Diatomaceous Earth: earth or soil composed of the skeletal remains of minute planktonic, unicellular or colonial algae.

Fly Ash: a powdery by-product of burning coal.

Hydraulic: used in this text, relating to the ability of a material to react with water and harden in its presence.

Hydraulic Cement: a binder material which reacts with water to form a harden water-resistant material. The colloidal calcium silicate hydrates, which are formed when silica reacts with lime and water, are responsible for the hydraulic hardening process.

Hydraulic Lime: product produced by burning argillaceous or silicious limestone at temperatures not less than 1000 degrees celsius. When showered with water, the product slakes possessing hydraulic properties.

Natural Cement: a cement made from burning argillaceous limestone, or other suitable natural rock, at temperatures from 900 to 1300 degree celsius. The product does not slake, but possesses hydraulic properties.

Portland Cement: a manufactured cement made by pulverizing the product made by heating to approximately 1450 degrees celsius; a definite proportion of silica, alumina and calcareous materials. Gypsum is added to control the hardening.

Puzzolan Cement: a cement made by the reaction at room temperature of reactive silica, slaked lime and water. Reactive silica can be found in nature in the form of volcanic ash or can be manufactured such as industrial fly ash.

Reactive Silica: silica brought into its reactive state by breaking up the compound it has formed with other materials. An example is the heating of Kaolinite clay to approximately 650 degrees celsius, thereby setting free the silica which is ready to react and form other compounds.

Reinforced Concrete: a composite building material using concrete and steel. Concrete which has high compression strength is used to resist compression stresses, but having very low tensile strength, steel is added to resist the tensile stresses. The two materials are very compatabile, both physically and chemically.

Rotary Kiln: a furnace used to burn or process materials at high temperature, cylindrically shaped and inclined to permit rotation and more uniform burning of processed materials.

Shear: the tendency for one body to slide with respect to an adjacent body.

Silica: major constituent of most natural rocks. It is often found in the form of quartz rocks, quartz sand and sandstone.

Slaked Lime: lime which has been heated and quenched with water causing the lime to crumble and the formation of carbonate compounds.

Soil-Cement: a mixture of cement, soil and water; the cement added to soil or earth to provide additional strength and stability; normally part of base course or supporting course of pavement.

Superelevated Curve: the raising of the outside pavement edge around a curve to retard the tendency for a vehicle to slip.

Tabby or Tapia: a mixture of burned hydraulic lime, pebbles or oyster shells, sand and water.

Tensile Stresses: the resistance that a body exerts subject to a pulling action that tends to elongate the body.

Viaduct: a bridge characterized by a series of arches.

PHOTOGRAPHS

Ruins of a row of slave quarters constructed of tabby in the early 1800's on the Kingsley Plantation, St. George Island (Source: Klingman 1979).

Carriage house constructed of tabby on the Kingsley Plantation,
St. George Island (Source: Klingman 1979).

Overseers quarters constructed of tabby on the Kingsley Plantation, St. George Island (Source: Klingman 1979).

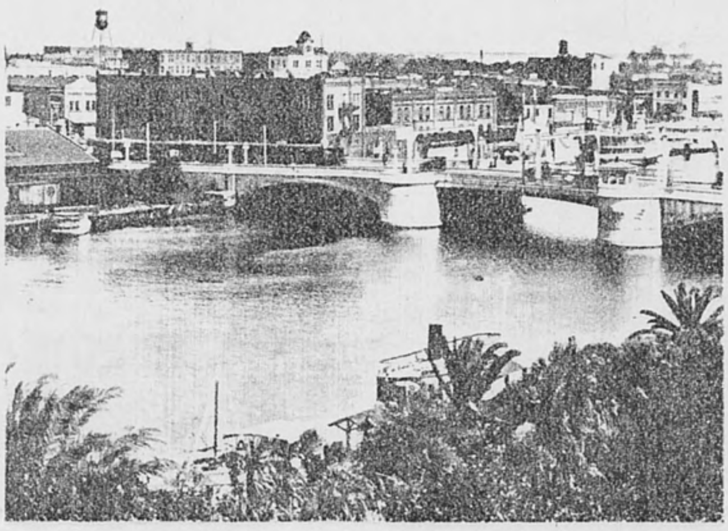
Ruins of tabby house once occupied by Houston MacIntosh adjacent to the Kingsley Plantation around 1800 (Source: Klingman 1979).

The Villa Zorayda in St. Augustine. Built in 1884 by Franklyn Smith, it was the first house in Florida built of portland cement concrete (Source: Weavil 1982).

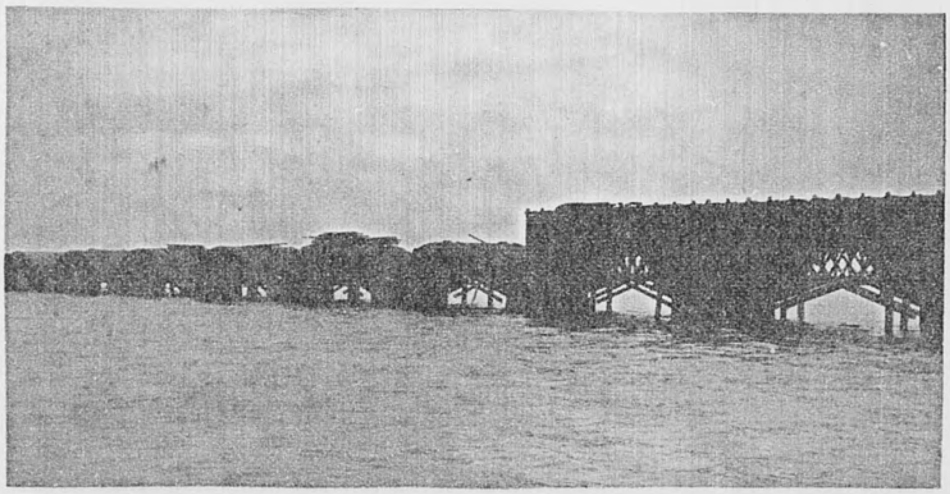
The Villa Zorayda in St. Augustine. This close-up view details the form lines and coquina aggregate (Source: Weavil 1982).

Warden Castle built in 1887 in St. Augustine (Source: Weavil 1982).

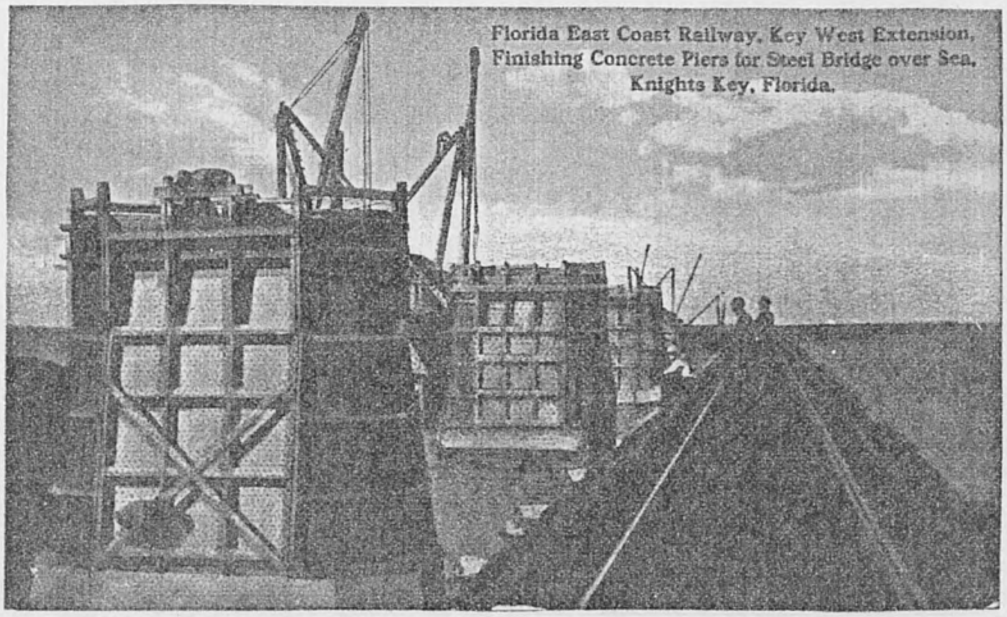
The Alcazar Hotel was completed in 1888 in St. Augustine and serves as City Hall and Lightner Museum (Source: Weavil 1982).



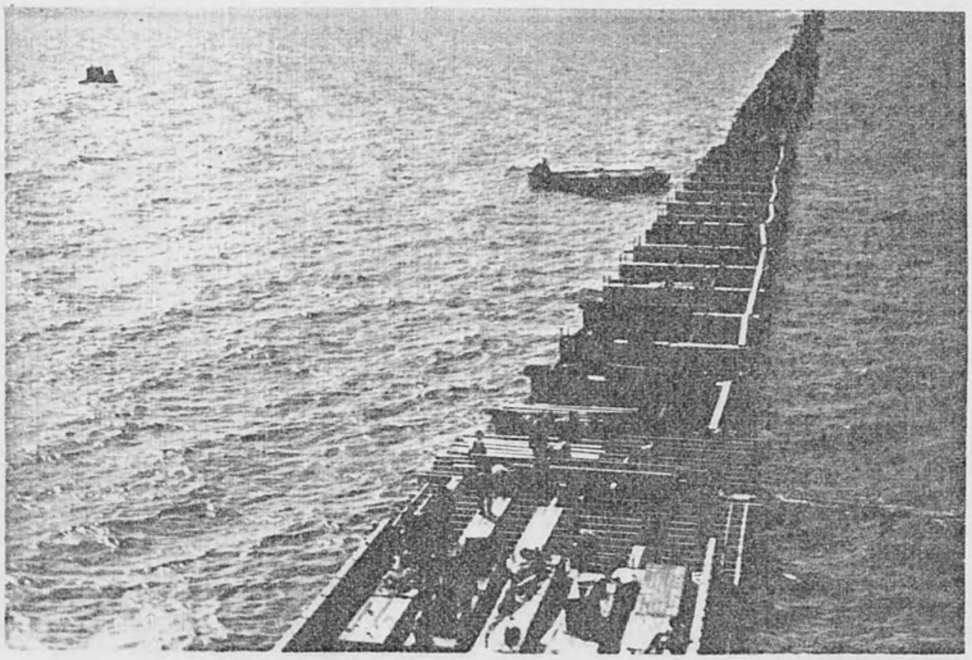
The Lafayette Street Bascule type bridge in Tampa (Source: State Photographic Archives).



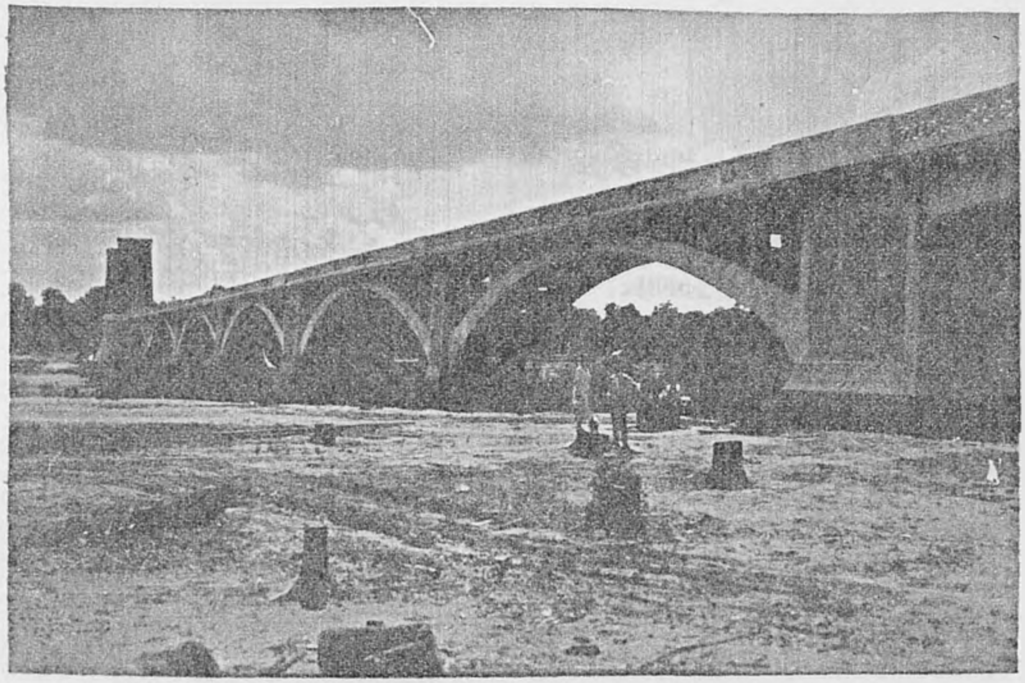
Construction of Long Key Viaduct of the Florida East Coast Railway's Key West Extension. Opened to train traffic February 5, 1908 (Source: State Photographic Archives).



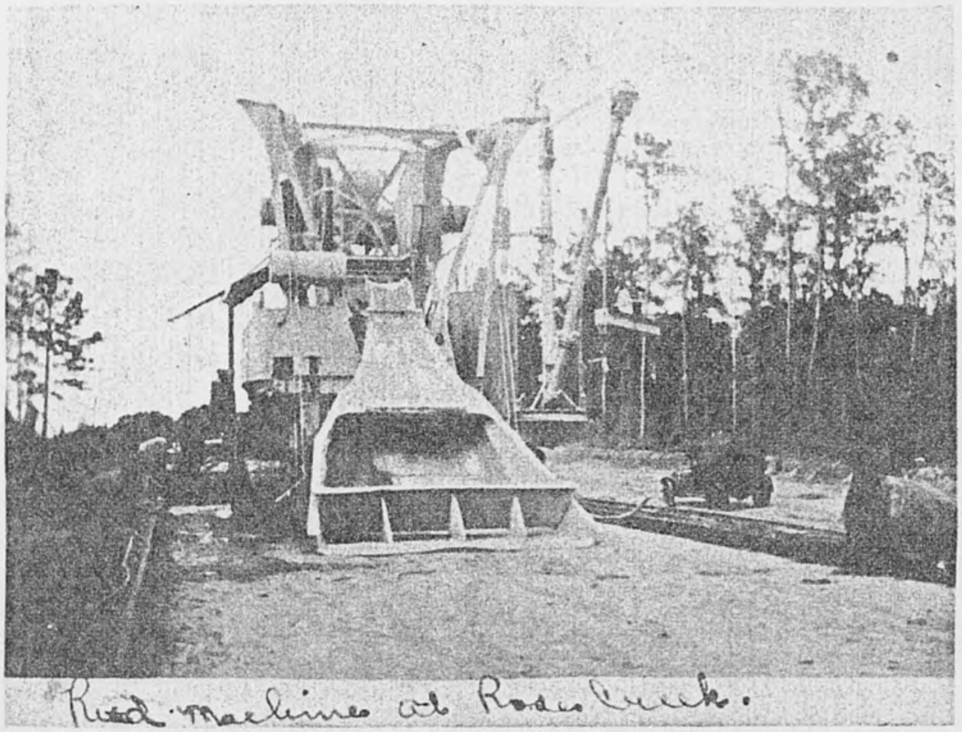
Finishing concrete piers for steel bridge at Knights Key, part of Florida East Coast Railway's Key West Extension (Source: State Photographic Archives).



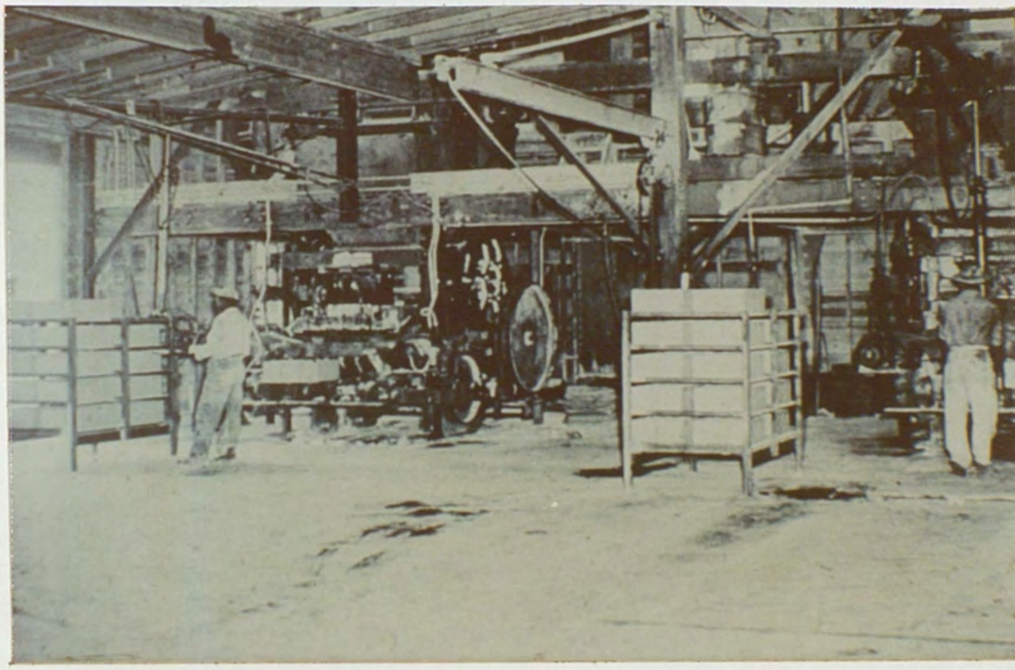
Construction of Gandy Bridge across Tampa Bay in 1922 (Source: State Photographic Archives).



The Victory Bridge at Chattahooche crossing the Apalachicola River opened June 20, 1922 (Source: State Photographic Archives).



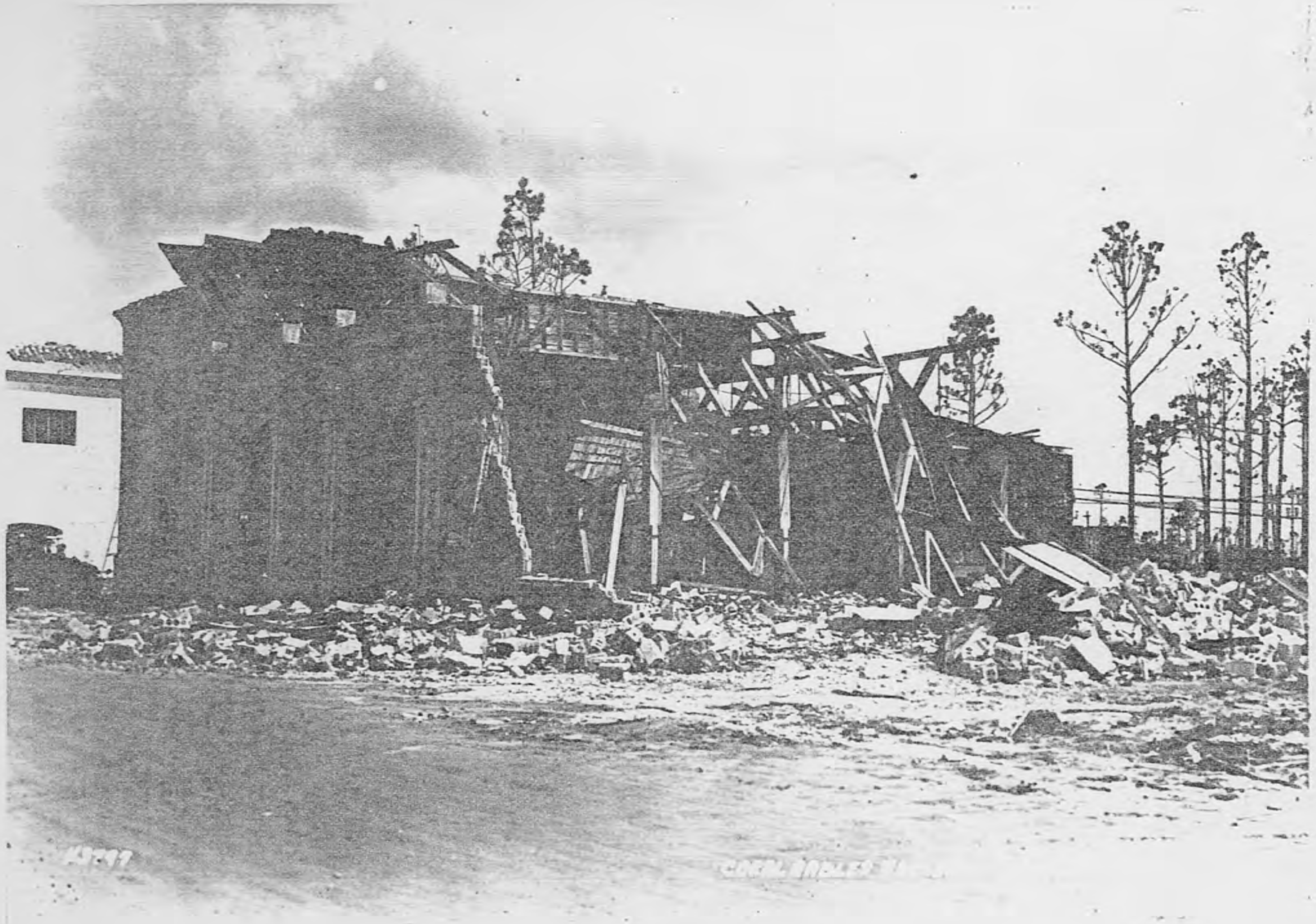
Concrete mixer used in highway construction by C. F. Lytle Construction Company during early 1920's (Source: State Photographic Archives).



Rinker Material Corporation's first block plant located in West Palm Beach in 1938. Production capacity was 2,000 blocks per day (Source: Rinker Materials Corporation).

In 1934 Rinker Materials Corporation introduced ready-mixed concrete to Florida. These GMC trucks were each equipped with a 1 1/2 cubic yard Rex mixer and were purchased for $2,000.00 each (Source: Rinker Materials Corporation).

Hotel Kelly in Gainesville around 1925 (Source: Florida Photographic Archives).



Coral Gables warehouse after hurricane in 1926. Such damage was responsible for adoption of building codes requiring reinforced concrete tie beams (Source: Florida Photographic Archives).

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